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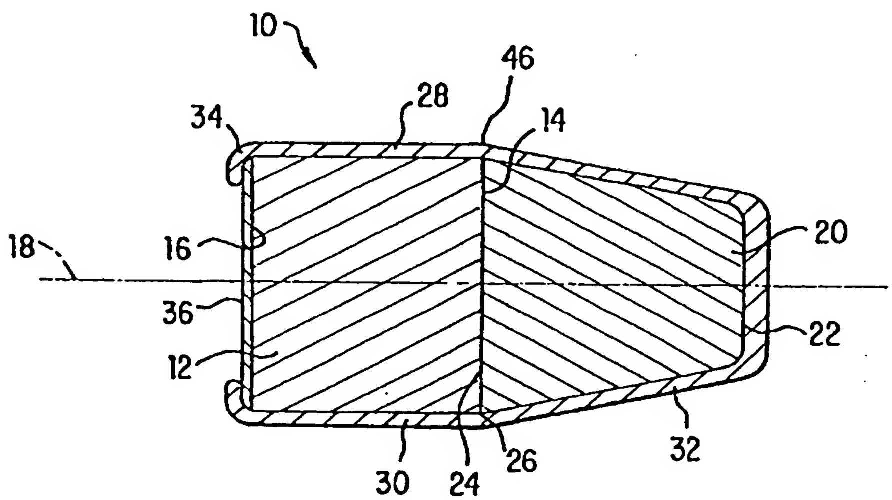
(71) Applicant: OLIN CORPORATION [US/US]; 350 Knotter Drive, P.O. Box 586, Cheshire, CT 06410-0586 (US).

(72) Inventors: VALDEZ, Anthony, F.; 6433 Godfrey Road, Godfrey, IL 62035 (US). MULDROW, Howard, K.; 4 Prairie Haute, St. Charles, MO 63301 (US). ROBINSON, Peter, W.; 21 Arrowhead Lane, Branford, CT 06405 (US).

(74) Agents: ROSENBLATT, Gregory, S. et al.; Wiggin & Dana, One Century Tower, New Haven, CT 06508-1832 (US).

(54) Title: DUAL CORE JACKETED BULLET



(57) Abstract

There is provided a lead-free small arms projectile (10) that deforms on impact with a target to rapidly dissipate the momentum of the projectile (10), minimizing penetration of the target. The projectile (10) has a jacket (28) that surrounds a first core (12) located in a rearward portion (30) of the jacket (28) and a second core (20) located in a forward portion (32) of the jacket (28). This second core (20) has a low yield strength and a tensile strength to yield strength ratio such that on impact, the first core (12) compressively deforms the second core (20), causing the seond core (20) to expand laterally outward from the target, increasing the surface area of the projectile (10) and dissipating the momentum imparted by the projectile (10).

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DUAL CORE JACKETED BULLET

This invention relates to a jacketed small arms projectile having two axially aligned cores encased within the jacket. More particularly, a forward core has a lower density and a lower yield strength than a rearward core. On impact, the forward core is outwardly deformed, causing the projectile nose to mushroom, dissipating projectile energy and limiting penetration of a target.

A conventional small arms projectile such as a bullet for a 9 millimeter hand gun, has a lead core encased in a copper alloy jacket. The high density of lead results in the rapidly moving projectile having a high energy. The lead deforms when subjected to the compressive forces of impact with a target. On impact, the bullet mushrooms, thereby increasing the surface area of the bullet nose causing a rapid dissipation of energy.

Millions of rounds of small caliber ammunition are fired yearly at target ranges. The accumulation of lead from these projectiles is an environmental hazard that makes the clean up of spent rounds and the conversion of the range to other applications difficult and expensive.

There has been a search for alternatives to lead in small arm projectiles. Among the materials evaluated were solid steel and solid copper projectiles. Commonly owned United States Patent No. 5,399,187 to Mravic et al. discloses sintered composites having a high density component and a low density component that achieve a density and ballistic properties similar to that of a lead core projectile.

Unlike lead core bullets, the aforementioned alternatives tend to penetrate a target with minimal mushrooming. Mushrooming is important at the target range to prevent damage to the range backstop that is typically steel. Mushrooming also minimizes ricochet when the projectile hits the backstop or another hard target.

A small number of the small arms projectiles are illegally fired at another person. If that person is a law enforcement agent, wearing a bullet-proof vest, it is imperative that the bullet mushroom and not penetrate the vest. Most vests are manufactured from "KEVLAR", a high strength aromatic polyamide manufactured by DuPont (Wilmington, DE).

Accordingly, the solid copper and solid steel projectiles are unsuitable for this type of small arm projectile and there remains a need for a small caliber projectile that has the ballistic and deformation properties of a jacketed lead core projectile.

Accordingly, it is an object of the invention to provide a small caliber projectile having a reduced lead content that resists penetration of a target. It is a feature of the invention that the projectile is jacketed and has a dual core encased in the jacket. Another feature of the invention is that the forward one of the cores has both a density and a yield or crush strength that is less than the rearward one.

It is an advantage of the invention that the forward core deforms on impact causing the projectile nose to mushroom and resist penetration of a target. It is another advantage that through

proper selection of the two cores, the projectile has a density and ballistic properties similar to that of a jacketed lead core projectile. It is an advantage that one or both of the cores can be lead free reducing the environmental hazard of the projectiles.

In accordance with the invention, there is provided a deformable projectile. This projectile includes a jacket that has a yield strength effective to deform on impact from the energy imparted by the projectile. The jacket defines a cylindrical space having a first internal volume and an ogival nose that extends from a first end of the cylindrical body that defines a frustoconical space having a second internal volume.

A first core occupies substantially all of the first volume and a second core abuts the first core and occupies substantially all of the second internal volume. The second core has a low yield strength and a tensile strength to yield strength ratio effective to compressively deform on impact with a target. The total mass of the projectile is less than 250 grains (16.2 grams).

The above-stated objects, features and advantages will become more apparent from the specification and drawings that follow.

Figure 1 illustrates in cross-sectional representation a full metal jacket projectile in accordance with the invention.

Figure 2 graphically illustrates the relationship between tensile stress and elongation.

Figure 3 graphically illustrates the relationship between compressive stress and elongation.

Figure 4 illustrates in cross-sectional representation a hollow point projectile in accordance with the invention.

Figures 5-7 illustrate the mushrooming of full metal jacket projectiles of the invention following impact with Kevlar target.

Figure 8 illustrates the mushrooming of a control lead core bullet on impact with a Kevlar target as known from the prior art.

Figure 1 shows in cross-sectional representation a deformable projectile 10 in accordance with the present invention. The deformable projectile 10 has a first core 12 generally in the shape of a right cylinder having a front face 14 and a rear face 16 both generally perpendicular to a longitudinal axis 18 of the deformable projectile 10.

A second core 20 is generally shaped as a truncated cone or frustrum. The second core 20 has a front face 22 and a rear face 24. The rear face 24 is in an abutting relationship with the front face 14 of the first core 12. At the interface 26 of the first core 12 and second core 20, the two cores may physically contact, be in a spaced relationship or be physically joined together such as by an adhesive, a reactive metal braze or other suitable medium. A preferred joining material is a thermosetting epoxy.

A jacket 28 usually encases the first 12 and second 20 cores. However, it is within the scope of

the invention to physically join the first core 12 to the second core 20 and eliminate the jacket 28.

The jacket 28 is formed from a ductile material that will deform and resist rupture on impact with a target. Preferably, the jacket 28 is formed from copper, aluminum or an alloy thereof. Copper alloys are preferred for the jacket material with copper alloy C226, having the nominal composition, by weight, of 13% zinc and 87% copper being most preferred.

The jacket 28 has a hollow cylindrical portion 30 surrounding the sidewalls of the first core 12. The jacket 28 further includes a hollow ogival nose portion 32 surrounding the sidewalls and the front face 22 of the second core 20. Preferably, the inside diameter of the hollow cylindrical portion 30 is about equal to the diameter of the first core and the inside diameter of the hollow ogival nose portion is about equal to the diameter of the second core.

The first core 12 and the second core 20 may be constrained within the jacket 28 solely by mechanical contact with the jacket or may be bonded to the inside surfaces of the jacket such as through the use of a solder or polymeric adhesive to prevent jacket separation. The preferred solders are lead free, and most preferably, a tin base alloy such as tin/zinc or tin/silver.

The jacket 28 extends beyond and wraps around, as crimp 34, the rear face 16 of the first core 12. An encapsulation disk 36, generally a thin, on the order of 0.25 mm (0.010 inch) thick, sheet of copper alloy C260 (nominal composition, by weight, 30% zinc

and 70% copper) abuts the rear face 16 and is held in place by crimp 34. The encapsulation disk 36 prevents the obturation of the second core 20 through the back end of the jacket 28 during projectile flight or on impact.

When the deformable projectile 10 strikes a target, the first core 12 drives into the second core 20 causing the second core to expand laterally along the surface of the target. This expansion increases the surface area over which the energy of the projectile is dissipated, minimizing penetration. It is desirable that the projectile either not penetrate or only minimally, less than about 2.54 mm (0.1 inch), penetrate relatively soft targets such as Kevlar or plywood. When striking a hard target, such as a steel backstop, the deformable projectile should not dent or mar the hard target. To achieve this objective, the diameter of the nose portion of the projectile should increase, in diameter, by at least 30% on impact, and preferably, by more than 50% on impact.

Any second core 20 that achieves this result on impact is suitable. The preferred materials for the second core 20 have a combination of a low yield strength, little or no work hardening after the second core 20 has yielded and a high compressive ductility.

Figures 2 and 3 graphically illustrate these mechanical properties of the second core. In Figure 2, the yield strength is depicted by reference point 38 and represents the stress at which a material exhibits a deviation from proportionality of stress and strain. The yield strength of the second core

is sufficiently low to effectively compressively deform on impact with the target. Because the compression is driven by interaction with the first core, a range of materials can be used as the second core that would not adequately deform if used alone or would lack sufficient mass to provide ballistic properties similar to lead.

The yield strength, measured at room temperature of 20°C, of the second core is preferably below 68.95 MPa (10 ksi), more preferably below about 34.48 MPa (5 ksi) and most preferably, below about 20.69 MPa (3 ksi).

As illustrated in Table 1, zinc is a most preferred metal for the second core due to the very low yield strength. Aluminum and copper, unsuitable when used alone, also form effective second cores. If lead contamination is not a concern, the second core may be formed of lead or a lead alloy.

TABLE 1

Core Material	Yield Strength MPa	(ksi)	Tensile Strength MPa	(ksi)
Zinc	≤6.9	(≤1)*	103.5	(15)
Aluminum (Alloy 1100, T-0 temper)	24.2	(3.5)	107.0	(15.5)
Copper (Alloy 102, annealed)	41.4	(6)	220.8	(32)

* Zinc constantly yields, the metal has no identifiable minimum yield point.

In addition to a low yield strength, the second core has minimal work hardening when compressed. This is indicated by a material having a tensile strength 40 close to the yield strength 38. The tensile strength is defined as the maximum stress (tensile or compressive) that a material can sustain without fracture. In an ideal material for the second core, the ratio of the tensile strength to the yield strength approaches 1 as indicated by broken line 42 of Figure 2, indicative of a material with minimal work hardening during compression or tension.

On impact, the first core compressively deforms the second core against the target. The stresses applied to the second core are not tensile, rather compressive as illustrated in Figure 3. Compressive strength values are not readily obtained and are dependent on the experimental testing method. Applicants believe that the tensile values are sufficiently related to the compressive values and may be used to specify materials for the second core.

The second core need not be a pure metal, but may be a metal alloy or metal compound, provided that the mechanical property considerations are satisfied. In addition, the core material may be in the form of a powder or spheres, optionally packed, compacted or sintered. The second core need not be a metal and may be a powder, or compacted powder, with a low crush strength and a high flow rate in compression such as calcium carbonate, selected waxes and selected polymers. The second core may further constitute a gel, a liquid or a gaseous fluid. However, the force exerted by the second core must be sufficient to deform the jacket. Suitable liquid materials for the second core are high viscosity greases, such as open gear greases satisfying the requirements of ASTM (American Society for Testing and Materials) specification 85-115.

The first core is formed from a material having a sufficiently high density to provide the projectile with ballistic properties similar to that of a lead core projectile. Lead has a density of 11.3 gm/cm^3. The density of the material constituting the first core should be at least 7.5 gm/cm^3 and preferably the density is at least 9 gm/cm^3. Deformation is to be concentrated in the second core, so the yield strength of the first core should be greater than that of the second. Suitable materials for the first core include iron, tungsten, molybdenum and alloys thereof. Preferred are tungsten compounds such as tungsten carbide and ferro-tungsten. Most preferred is a sintered copper ferro-tungsten or a sintered iron ferro-tungsten

core. The sintered materials are preferred since the frangibility of the first core can be controlled.

It is desirable that all the energy associated with both cores 12, 20 is dissipated during flattening of the second core 20 without damage to the target. Therefore, it is desirable that the first core not excessively penetrate or damage the target. In one embodiment, this is achieved by having a first core that disintegrates at a low compressive stress, such as less than about 413.7 MPa (60,000 psi) and preferably at less than about 310.3 MPa (45,000 psi).

Such a material for the first core can be formed by compacting, optionally followed by sintering, a mixture of ferro-tungsten particles and copper particles. In a typical powder sample, approximately 80% of the ferro-tungsten particles have an average diameter of from 40 microns to 500 microns. Approximately, 90% of the copper particles have an average diameter of from 3 microns to 50 microns. Sintering is at a temperature of between 650°C to about 1,000°C. While sintering can be carried out in air or nitrogen, sintering in hydrogen is preferred. Minimal compaction is applied to the powder such that a frangible compact is formed.

With reference back to Figure 1, the volumes of the first core 12 and of the second core 20 are defined by the jacket configuration. The first core 12 occupies that internal portion of the jacket up to an inflection point 46 at the intersection of the hollow cylindrical portion 30 and the hollow ogival

nose portion 32. Since the first core is rigid, it can not be deformed into the ogival nose portion 32 and therefore, terminates either at the inflection point 46 or rearward of the inflection point. Since it is desirable to maximize the bullet density to achieve ballistic properties similar to lead, preferably the first core 12 terminates at the inflection point 46. The more deformable second core 20 occupies the volume defined by the hollow ogival nose portion 32 and any portion of the hollow cylindrical portion 30 forward of the first core 12.

As illustrated in Figure 4, the dual core bullet of the invention is applicable to hollow nose bullets 50. In this embodiment, the jacket 28 envelopes the first core 12 and second core 20. The jacket is crimped 51 about a nose portion 52 of the projectile 50. A blind hole 54 extends inward from the nose portion 52 with the crimp 51 extending part way into the blind hole 54.

The weight of the assembled bullet (first core, second core and jacket) is dependent on the caliber and the bullet type. For most small arms application the assembled weight will be less than 16.2 gm (250 grains) and preferably less than 13.0 gm (200 grains). For 9 mm bullets, the preferred assembled weight is from 6.5 gm (100 grains) to 9.7 gm (150 grains) with a most preferred assembled weight of from 8.2 gm (127 grains) to 9.5 gm (147 grains).

The optimum velocity is also dependent on the caliber and bullet type. For a full metal jacket 9 mm assembled bullet, the optimum velocity is from 290 m/s (950 feet per second) to 311 m/s (1020 feet

per second) as measured 4.6 m (15 feet) from the muzzle.

While the entire projectile is preferably lead free, lead may constitute or be incorporated into one or more of the projectile constituents to exploit the density or ductility of the metal.

The advantages of the dual core projectile of the invention will become more apparent from the examples that follow.

EXAMPLES

Example 1

A projectile having a first core of sintered copper ferro-tungsten and a second core of lead was encased in a copper alloy C226 jacket. The projectile had an assembled weight of 9.53 gm (147 grains) and was inserted into a 9 mm cartridge casing. The bullet was fired at a Type II Kevlar vest at a velocity of 308.4 m/s (1,011 feet per second). As illustrated in Figure 5, the diameter of the nose mushroomed by 61% and there was no penetration of the Kevlar.

Example 2

A projectile having a first core of sintered copper ferro-tungsten and a second core of calcium carbonate powder was encased in a copper alloy C226 jacket. The projectile had an assembled weight of 6.61 gm (102 grains) and was inserted into a 9 mm cartridge casing. The bullet was fired at a Type II Kevlar vest at a velocity of 333.7 m/s (1,094 feet per second). As illustrated in Figure 6, the

diameter of the nose mushroomed by 54% and there was no penetration of the Kevlar.

Example 3

A projectile having a core formed entirely of copper ferro-tungsten powder that was compacted without sintering, *i.e.* "a green core", was encased in a copper alloy C226 jacket. The projectile had an assembled weight of 9.4 gm (145 grains) and was inserted into a 9 mm cartridge casing. The bullet was fired at a Type II Kevlar vest at a velocity of 299.2 m/s (981 feet per second). As illustrated in Figure 7, the diameter of the nose mushroomed by 39% and there was no penetration of the Kevlar.

Control

A projectile having a core formed entirely of lead was encased in a copper alloy C226 jacket. The projectile had an assembled weight of 9.53 gm (147 grains) and was inserted into a 9 mm cartridge casing. The bullet was fired at a Type II Kevlar vest at a velocity of 308$\pm$3.1 m/s (1010$\pm$10 feet per second). As illustrated in Figure 8, the diameter of the nose mushroomed by 70% and there was no penetration of the Kevlar.

It is apparent that there has been provided in accordance with the present invention a dual core projectile that fully satisfies the objects, means and advantages set forth hereinabove. While the invention has been described in combination with embodiments thereof, it is evident that many alternatives, modifications and variations will be

apparent to those skilled in the art in light of the foregoing description. Accordingly, it is intended to embrace all such alternatives, modifications and variations as fall within the spirit and broad scope of the appended claims.

IN THE CLAIMS:

1. A deformable projectile (10,50), characterized by:

a jacket (28) having a yield strength effective to deform on impact, said jacket (28) defining

a cylindrical space (30) having a first internal volume, and

a ogival nose portion (32) having a second internal volume that extends from a first end of said cylindrical space (30);

a first core (12) occupying substantially all of said first internal volume; and

a second core (20) abutting said first core (12) and occupying substantially all of said second internal volume, wherein said second core (20) has both a yield strength and a tensile strength to yield strength ratio, effective to compressively deform on impact with a target, the total mass of said projectile (10, 50) being less than 16.2 grams.

2. The deformable projectile (10, 50) of claim 1 characterized in that said second core (20) has a yield strength of less than 68.95 MPa.

3. The deformable projectile (10, 50) of claim 2 characterized in that said second core (20) is selected from the group consisting of copper, aluminum, zinc lead and alloys thereof.

4. The deformable projectile (10, 50) of claim 2 characterized in that said second core (20) is selected from the group consisting of low crush strength powders and compacted powders.

5. The deformable projectile (10, 50) of claim 2 characterized in that said second core (20) is selected from the group consisting of waxes, polymers, gels, fluids and liquids.

6. The deformable projectile (10, 50) of claim 2 characterized in that said first core (12) has a density in excess of 7.5 gm/cm^3.

7. The deformable projectile (10, 50) of any one of claims 1-6 characterized in that said first core (12) is selected from the group consisting of iron, tungsten, molybdenum and alloys thereof.

8. The deformable projectile (10, 50) of any one of claims 1-6 characterized in that said jacket (28) is selected from the group consisting of copper, aluminum and alloys thereof.

9. The deformable projectile (50) of claim 8 characterized in that an end of said hollow ogival nose portion (32) of said jacket (28) opposite said hollow cylindrical body (30) is open and extends into a blind inwardly extending hole (54) formed in said second core (20).

10. The deformable projectile (10, 50) of claim 8 characterized in that an end of said hollow cylindrical body (30) of said jacket (28) opposite said hollow ogival nose portion (32) is sealed with an encapsulation disk (36).

11. The deformable projectile (10, 50) of claim 8 characterized in that said first core (12) is bonded to said second core (20).

12. The deformable projectile (10, 50) of claim 8 characterized in that said first core (12) and said second core (50) are bonded to said jacket (28).

13. A deformable projectile (10) characterized by:

a right cylindrical first core (12) having a front face (14) and an opposing rear face (16);

a truncated cone second core (20) having front face (22) and a rear face (24); and

a joining material bonding said front face (14) of said first core (12) to said rear face (24) of said second core (20).

14. The deformable projectile (10) of claim 13 characterized in that said second core (20) has a yield strength of less than 68.95 MPa.

15. The deformable projectile (10) of claim 14 characterized in that said second core (20) is selected from the group consisting of copper, aluminum, zinc, lead and alloys thereof.

16. The deformable projectile (10) of claim 15 characterized in that said first core (12) has a density in excess of 7.5 gm/cm^3.

17. The deformable projectile (10) of claim 16 characterized in that said first core (12) is selected from the group consisting of iron, tungsten, molybdenum and alloys thereof.

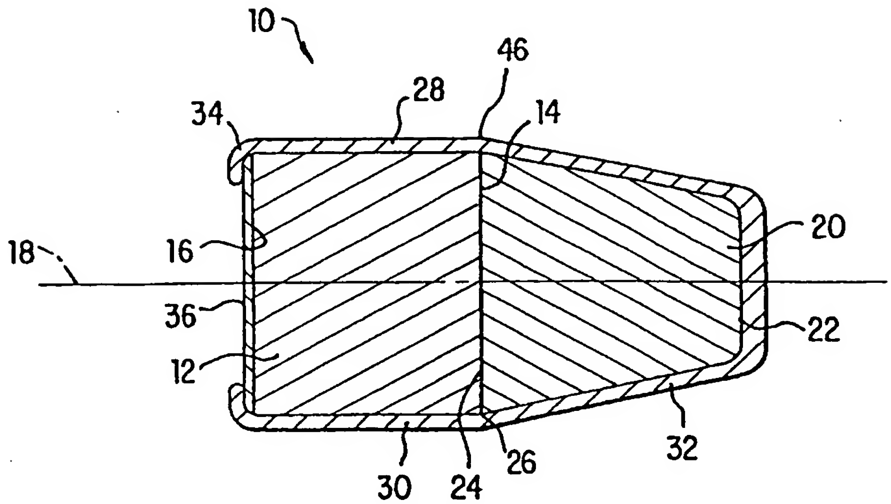


FIG. 1

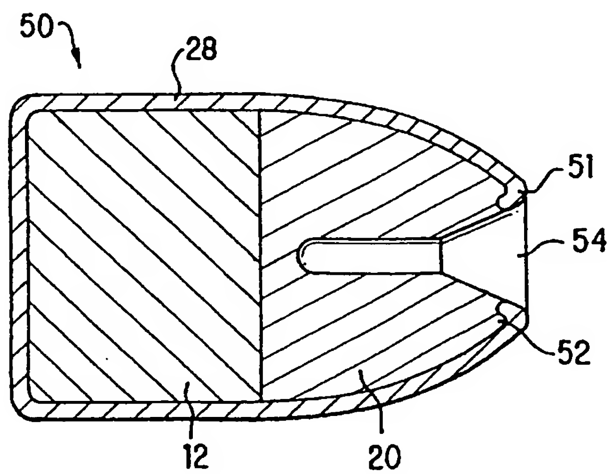
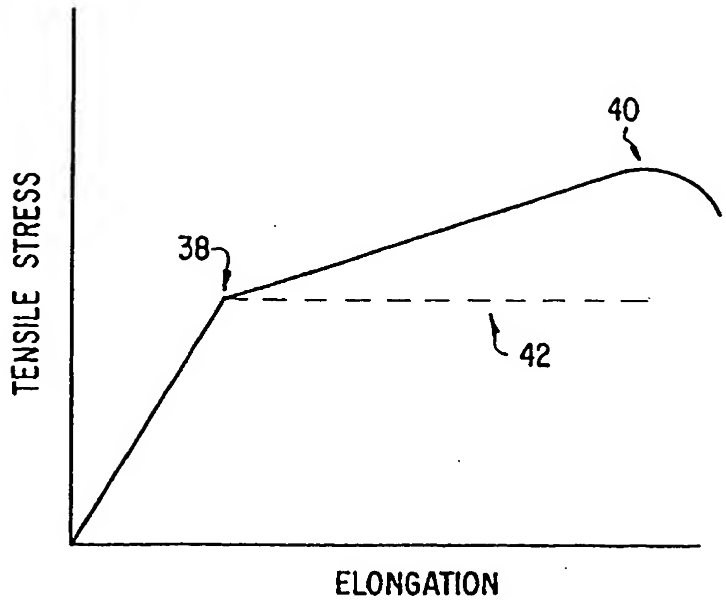


FIG. 4


TENSILE STRESS
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38
42
ELONGATION

FIG. 2

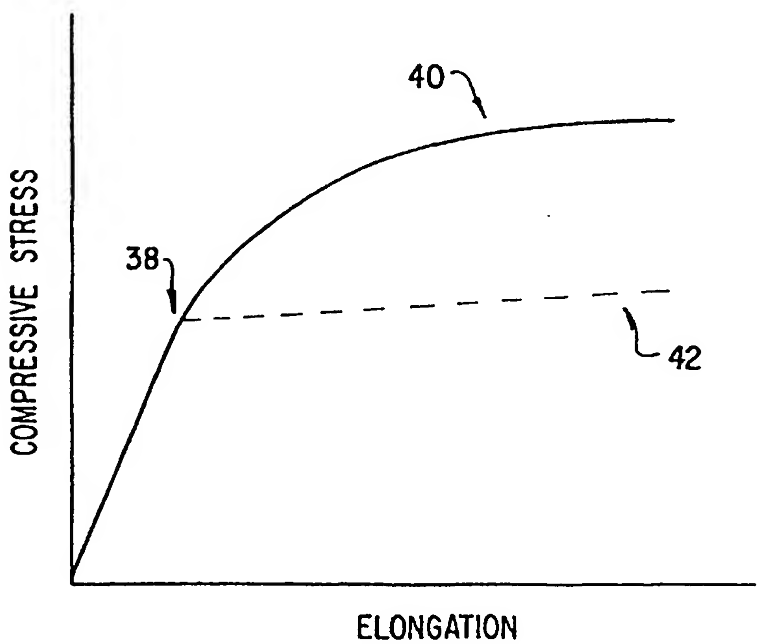
COMPRESSIVE STRESS
40
38
42
ELONGATION

FIG. 3

FIG.5

FIG.6

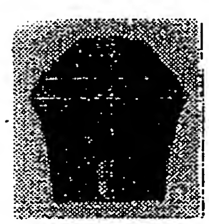

FIG.7

FIG.8
PRIOR ART

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/17664

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F42B 12/34
US CL :102/509
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 102/501, 502, 506-510, 511, 513-519, 529

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, Projectile # or bullet #, calcium carbonate, grease, Copper C226

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 3,720,170 (GODFREY) 13 March 1973, see entire document.	1-3, 6-17
Y	US, A, 4,610,061 (HALVERSON) 09 September 1986, see entire document.	9
Y	US, A, 3,230,886 (WOODRING) 25 January 1966, see entire document.	1, 2, 4, 6, 8, 11, 13-17
Y	GB, A, 887,124 (DYNAMITE NOBEL) 17 January 1962, see Figure 1 and lines 47-53 of page 1.	12
Y	US, A, 4,517,898 (DAVIS ET AL) 21 May 1985, see Figures 3-6.	1, 2, 4, 6, 8, 11, 13-17
Y	FR, A, 374,726 (DEPORT) 21 June 1907, see entire document.	1-4, 6-12

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 1,512,026 (HOLDEN ET AL) 21 October 1924, see entire document.	1, 2, 5-12
Y	GB, A, 14,717 (MAXIM) 03 March 1900, see Figures 1 and lines 25-40 of page 2.	1, 2, 5-12
Y	US, A, 4,338,862 (KWATNOSKI ET AL) 13 July 1982, see entire document.	1, 2, 5, 6
Y	FR, A, 405,281 (COMPAGNIE) 24 December 1909, see entire document.	13-17
Y	CH, A, 360,312 (LEVINE) 30 March 1962, see entire document.	16, 17
A	US, A, 2,682,224 (BRAVERMAN) 29 June 1954.	
A	US, A, 4,664,664 (DRAKE JR.) 12 May 1987.	
A	DE, A, 37,952 (ZUNDHUTCHEN) 10 July 1909.	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/17664

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.